Multi-technique Studies Of Ionospheric Plasma Structuring

Sunanda Basu
Center for Space Physics
Boston University
725 Commonwealth Avenue
Boston, MA 02215
phone: (202) 404-1290 fax: (202) 767-9388 email: sbasu@bu.edu

Award Number: N00014-03-1-0593

LONG-TERM GOALS

Understanding of physical processes that lead to plasma structuring in the equatorial, mid and high-latitude ionosphere. Identifying the effects of such variability, generally known as ionospheric space weather, on the operation of various communication, navigation and surveillance systems.

OBJECTIVES

Establish major drivers that lead to structured ionospheric plasma in equatorial, mid and high-latitude regions. Investigate cascading of plasma structuring from large (~ hundreds of km) to small scales (~tens of m), which cause outages in space-based communication and GPS-based navigation systems.

APPROACH

Work on this project was started with investigations of large and small scale plasma structuring in the middle latitude ionosphere and their links to such structuring within the polar cap during magnetic storms. The diagnostic techniques used were measurements of total electron content (TEC) from GPS satellites and phase and amplitude scintillation measurements from a host of mid and high latitude stations. Coordinated measurements were utilized from the HF radar system known as Super Dual Auroral Network (SuperDARN) and the NASA IMAGE satellite. The PI herself is the primary person working on this problem with scientific colleagues providing data and related analysis of scintillations and TEC (Santimay Basu, AFRL, Cesar Valladares and Eileen MacKenzie, both of Boston College). The SuperDARN data were provided by Ray Greenwald of APL/JHU and the IMAGE data by Jerry Goldstein of SWRI.

WORK COMPLETED

The initial part of this analysis has been completed and a scientific presentation given at the IUGG Meeting in Sapporo, Japan in July 2003 on this topic. Some of the results presented are given in the next section.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE **Multi-technique Studies Of Ionospheric Plasma Structuring**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Center for Space Physics,,Boston University,725 Commonwealth Avenue,,Boston,,MA, 02215**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Understanding of physical processes that lead to plasma structuring in the equatorial, mid and high-latitude ionosphere. Identifying the effects of such variability, generally known as ionospheric space weather, on the operation of various communication, navigation and surveillance systems.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

RESULTS

In particular, we chose to study the middle latitude ionosphere as an important GPS-based navigation system has been developed for this region in the continental US. The Federal Aviation Administration is currently using a navigation system called the Wide Area Augmentation System (WAAS). WAAS provides GPS-based navigation to aircraft flying over the US. Such a system has been shown to be adversely impacted by magnetic storm induced TEC variations and TEC fluctuations that are recorded with GPS receivers (Dehel et al., 1999). Magnetic storms during the current solar maximum have caused serious ionospheric space weather effects at middle latitudes within the continental United States (Basu et al., 2001 and references therein). The ionospheric effects observed during the March 31, 2001 storm provide another example of severe large and small-scale perturbations in plasma density observed within the US.

Based on incoherent scatter radar observations during this March 31, 2001 storm at Millstone Hill located at mid-latitudes, Foster et al. (2002) observed large westward convecting storm enhanced densities (SED) in the ionosphere that correspond well with GPS maps of TEC. They considered that SED's arise from the erosion of the outer plasmasphere by strong subauroral polarization electric fields. The ionospheric effects for this magnetic storm provide a very good example of the issues involved. The storm was rather unique because the decrease of high-resolution SYM-H index (equivalent to 1-minute Dst) first occurred during the post-midnight time period over the eastern coast of the United States and a decrease of SYM-H also occurred in the recovery phase of the storm during midday in the same region. The ionospheric response, as measured by TEC variations and scintillation, was markedly different at these two different local times when SYM-H registered large changes with time. The onset of the storm occurred shortly after 0400 UT on March 31, 2001, and the SYM-H index decreased sharply to attain a minimum value of –450 nT at 0812 UT. This main phase of the storm corresponded to the local midnight time frame over the eastern United States as mentioned above. Figure 1 shows the scintillation index S4, recorded at 250 MHz from Fleetsat-7 plotted as a function of UT from Hanscom AFB, Massachusetts. Scintillations commencing at 0443 UT exceeded the saturation level of unity (which is equivalent to about 20 dB of peak-to-peak fluctuations) and corresponded to a 350-km ionospheric intersection at 39.8^0 N lat, 74.4^0 W long. During the recovery phase of the storm, SYM-H again showed a minor decrease at 16 UT and a major decrease at 18 UT that corresponded to the local noon period at the ionospheric intersection of scintillation observations. Three bursts of associated scintillation (exceeding 10 dB at 250 MHz) were recorded as shown in Figure 1.

Figure 2 shows the variation of the total electron content at Westford, MA (42.4^0 N, 71.5^0 E), recorded by the GPS receivers (at elevation angles greater than 60 degrees) of the International Geodynamic Service (IGS). Associated with the main phase of the storm, variations of TEC of 20 to 30 TEC units occurred with sharp temporal variations. This indicates the intrusion of the auroral oval into the local ionosphere. Later, associated with SYM-H decreases in the recovery phase of the storm between 16-18 UT that corresponds to local noon period at Westford, MA large TEC enhancements of 50 to 70 TEC units were recorded. However, the scintillations were not as severe and their spectral characteristics were quite different from those observed during the nighttime period. These post-noon events are to be attributed to penetration electric fields and storm enhanced densities associated with the erosion of the outer plasmasphere (Foster et al., 2002).

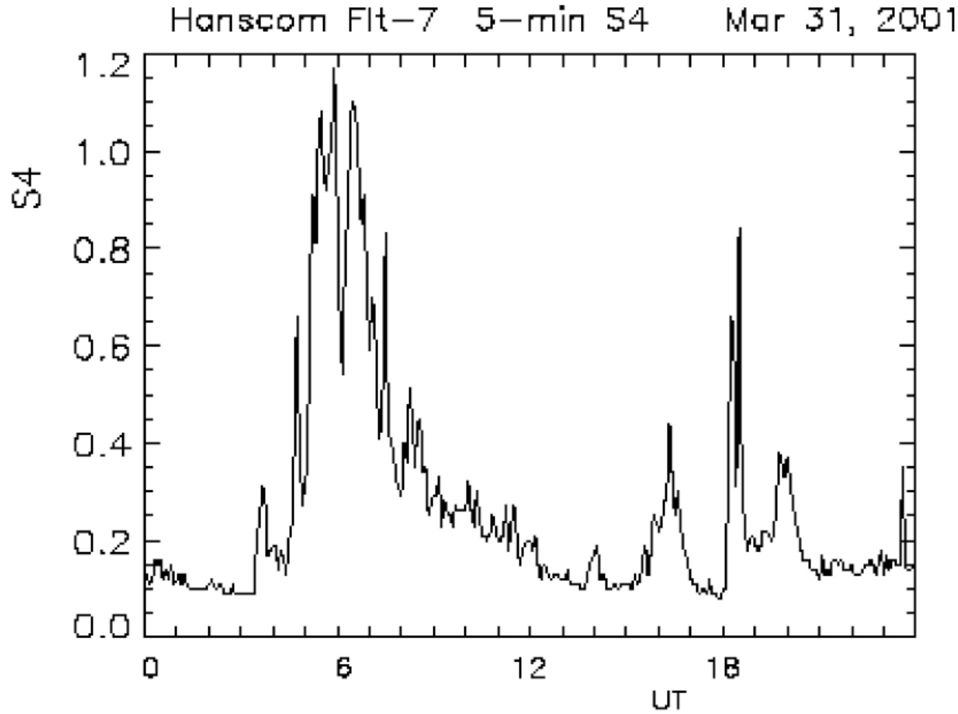

Figure 1. Scintillation index S4 at 250 MHz from the Fleetsat-7 satellite received at Hanscom Air Force Base, Massachusetts during the March 31, 2001 storm.

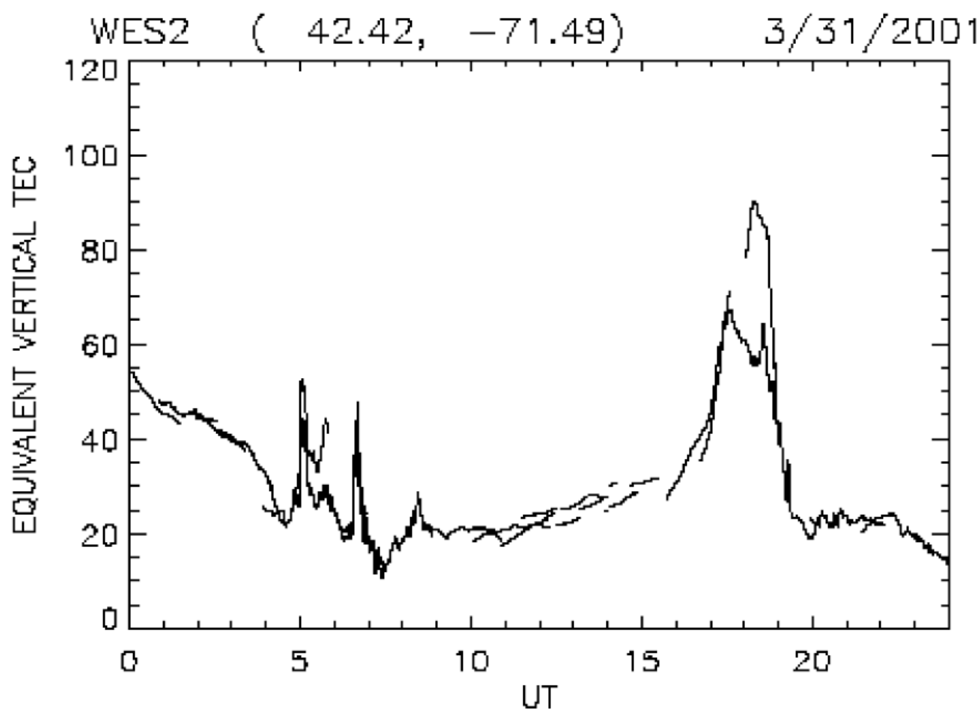

Figure 2. The equivalent vertical TEC measured using GPS satellites at elevation angles > 60^0 at Westford, Massachusetts (WES-2) on March 31, 2001

Thus these midlatitude storm effects provide a wonderful opportunity to delve into magnetosphere-ionosphere coupling processes, including shielding mechanisms responsible for the exclusion/penetration of high latitude electric fields, which have substantial impact on technological systems as well. Indeed, using the SuperDARN data, DMSP data of polar cap plasma densities and EUV images from the IMAGE satellite, we were able to track the small scale plasma density irregularities all the way through the cusp into the polar cap where they were found to be responsible for severe 250 MHz scintillations on quasi-stationary polar beacon links at Thule, Greenland (Basu et al., 2003). The generation mechanisms and technological impacts of these stormtime plasma density perturbations have been recognized as important topics for study by the Geospace Mission Definition Team of NASA's Living with a Star Program.

IMPACT/APPLICATIONS

The large TEC gradients and severe phase fluctuations at GPS frequencies, particularly in the nighttime period, caused a loss of lock in at least seven GPS receivers operating in Chatham, MA (Coster et.al., 2003). This was an adverse impact on the GPS-based navigation system WAAS mentioned above. The saturated amplitude scintillations at 250 MHz on the Fleetsat satellite is expected to impact DoD's satellite-based communication systems.

RELATED PROJECTS

A project which is related to plasma structuring in the equatorial region has been started. We are investigating the behavior of the nighttime (0230 LT) LORAAS airglow data at 135.6 nm data from the ARGOS satellite in the Guam sector, to see if we can identify airglow and plasma density patterns associated with scintillations observed at the AFRL Scintillation Network Decision Aid, SCINDA (Basu et al., 2002) site at Guam.

REFERENCES

Basu, Sunanda, S. Basu, C.E. Valladares, H.C. Yeh, S.-Y. Su, E. MacKenzie, P.J. Sultan, J. Aarons, F.J. Rich, P. Doherty, K.M. Groves, and T.W. Bullett, Ionospheric effects of major magnetic storms during the International Space Weather period of September and October 1999: GPS observations, VHF/UHF scintilllations, and in-situ density structures at middle and equatorial latitudes*, J. Geophys. Res., 106*, 30,389, 2001.

Basu, Sunanda, S. Basu, C.E. Valladares, and R.E. Sheehan, Ionospheric plasma structuring in the mid-latitude, cusp and polar cap regions during enhanced plasma convection, Presented at the International Union of Geodesy and Geophysics (IUGG) General Assembly, Sapporo, Japan, June 30, 2003 - July 11, 2003.

Basu, S., K.M. Groves, Sunanda Basu, and P.J. Sultan, Specification and forecasting of scintillations in communication/navigation links: current status and future plans, *J. Atmos. Solar Terr. Phys., 64*, 1745, 2002.

Coster, Anthea, John Foster, and Phillip Erickson, Monitoring the ionosphere with GPS, *GPS World,* pg.40, May 2003.

Dehel, T.K., K. Pham, and J. Sheftic, National Satellite Test Bed (NSTB) observations of the effects of ionospheric storms on a prototype Wide Area Augmentation System, *Proc. IONGPS*, San Diego, CA 1999.

Foster, J. C., P.J. Erickson, A.J. Coster, J. Goldstein, and F.J. Rich, Ionospheric signatures of plasmaspheric tails, *Geophys. Res. Lett., 29*, GL015067, 2002.

HONORS/AWARDS/PRIZES

The PI was selected Chair, Science Steering Committee of the Scientific Committee for Solar Terrestrial Physics (SCOSTEP) international program for the period 2004-2008 entitled “Climate and Weather of the Sun-Earth System (CAWSES)”.